Unsupervised Spatial Feature and Change Detection in RS Imaging

Fourth Interim Report

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1 April 1999

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Contract number: N 68171-98 C 9012

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	Form Approved
REPORT DOCUMENTATION PAGE	OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE April 1 1999	3. REPORT TYPE AND DATES COVERED Fourth Interim Report (Jan -March 8 1999

4. TITLE AND SUBTITLE Unsupervised Spatial Feature and Change Detection in RS and Imaging	5. FUNDING NUMBERS N68171-98-C-9012

6. AUTHOR(S)

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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING /MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

19990628 098

Main activities started:
- a clearer modular rebuild of the basic methodology implemented by the system, involving a clear separation of the main methodological elements;
- splitting off the new pixel-by-pixel classified image inspection mode in a non-volatile module, for separate operation;
- selecting (sub)classes and regions in a classified image for further analysis;
- experimentally start with spectral de-mixing, within (sub)classes, using RBF neural network technology;
- almost completed a users friendly, menu based, users interface;
- migrated the system from Java JDK 1.16 to Java JDK 1.2.

14. SUBJECT ITEMS Remote Sensing, Statistics, GIS, Neural Networks, Classification Methods, Optimization.	15. NUMBER OF PAGES 4
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

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(1) Scientific work during report period

During this period we started redesigning and extending the architecture of our system for unsupervised classification with an eye on its extension along the lines discussed and decided during our October 1998 workshop at CRREL-RS/GISC in Hanover.

1. A clearer modular rebuild of the basic methodology implemented by the system. This involves a clear separation of the main methodological elements:
- a) adaptive pixel *learning sample* selection:
    - homogeneous, without stratification;
    - homogeneous, with stratification;
    - biased random, with stratification;
    - local/global density selection.
- b) multivariate density based *unsupervised class detection*;
- c) the various *image classification* modes:
    - 1-NN (nearest neighbor) mode;
    - 1st PC (principal component) projection pursuit mode;
    - .....possible additional method.....
- d) the various *blending* modes:
    - no blending;
    - blending along 1st PC (principal component) axis;
    - blending within 2 PC (principal component) volume;
    - blending using 2nd generation Radial Basis Function (RBF) based neural network technology;
- ......possible additional methods.....

Especially the introduction of all combinations in the simultaneous application of modes c) and d), which was not possible in the earlier version of UNSUP, will be necessary in subsequent applications.

2. Splitting off the highly innovative pixel-by-pixel classified image inspection mode in a non-volatile module. In the earlier version of UNSUP this possibility was not saved and deleted when exiting a classification run. The implementation of this separation was accomplished during this period. This means:
- given a user accepted image classification, a closer pixel-by-pixel investigation can be done separately, at later moments;
- the underlying classified database is amenable to further analysis, using other analysis modules.

These possibilities are of extreme importance for further validation or elaboration regions and areas in the image in terms of the detected classes in the image.

3. Given a classified image:
- select the pixels in a specified class for further analysis.
- select a contoured region within the classified image to focus further analysis on this selection.

We have partly implemented these options, as they are necessary for the continuation of our project according to our proposal.

4. We have experimentally started with spectral de-mixing, within (sub)classes, using selections as mentioned ad 3. Spectral demixing is essential for targeted oil detection, snow area analysis or water pollution area detection. we have started to do this using the above mentioned RBF neural network technology.

5. We have almost completed a users friendly, menu based, users interface, which could facilitate considerably the use of the software in the further development of our methodological research along the lines of the proposal.

6. Finally, we have migrated the system from Java JDK 1.16 to Java JDK 1.2.

(2) **Research plans for the remainder of the period.**

During this period we received the disturbing news that further funding of this project beyond this reporting period (i.e. as of 1 April 1999) is not sure. We are very sorry if the continuation of this cooperative research project on behalf of the US Corps of Engineers in general, and in particular of its CRREL-RS/GISC staff, with whom we had such good and mutually stimulating contacts over the last four years, would come to an abrupt end. The consequence of this would be that the results, as mentioned above, as well as below, can not be further developed and completed, or made available to USACE and its CRREL-RS/GISC, because we then shall have to do so on our own account, if needed seeking other partners elsewhere in industry or within the European Union.

However, assuming restoration and continuation of this project and our precious relations with CRREL-RS/GISC we envisage the following further planning, along these main priorities, completing the rebuild and reengineering design projects mentioned above.

1. innovative optimization;

2. spectral de-mixing;

3. unsupervised change detection.

4. methods for evaluating classification error and accuracy.

We shall then proceed according to the following plan.

A). Study innovative improvements in algorithmic performance and classification accuracy.

This focuses on methodological and algorithmic (precision, convergence and speed) enhancement of the basic features of this set of unsupervised classification

procedures. Accuracy evaluation and measurement is here associated with the errors of misclassification, known in standard *supervised* classification methods such as in parametric discriminant analysis and trained artificial neural networks. As these methods are based on, and presuppose the matching of image pixels to *previously known* class or ground coverage parameters, the concepts of misclassification and errors of misclassification can be immediately defined and modeled in, for instance, the well known *confusion* matrices.

However, in non-parametric, unsupervised classification these concepts do not have an immediate meaning because, by definition, no such prior knowledge exists as the whole procedure aims to detect, define and generate *a posteriori* the system of classes as contained in the spectral information of a particular image and its subsequent mapping to the pixels of that image.

Hence there is no direct analogue here to the familiar confusion matrix. We propose to study possibilities to develop analogous measures and concepts in the context of the two levels that matter in our system of unsupervised classification:

>   (1) the *reliability* of the detected class system (how stable are its detected classes under pixel sampling and picture window);

>   (2) the *accuracy* of the pixel class mapping (are similar pixels mapped to the same class?).

A different problem is how classes and pixel mappings in an image correspond with available, usually occasional ground knowledge. This concerns the *validity* of the obtained set of classes and its image mapping. This we shall study and assess the examination of classification results for images with substantive patches of quality ground knowledge with two major purposes:

>   - *calibration* and *tuning*: do the known patches correspond to discernible classes, and which levels of classification parameters serve to get the best correspondence? (at what levels can clouds or vegetation be separated from water);
>   - *generalization potential*: does the coverage in a known patch correspond with that of other patches with the same class?

In order to enable this type of study it was decided that CRELL RS-GISC (Dr. LaPotin) will send us some images with lots of pin-pointed ground knowledge (*e.g.* oil-spill data , urban/rural, coastline areas, snow cover, flood data?), which are *sufficiently annotated* for us here to identify known patches of ground cover and use them for further quality assessment, validation and calibration.

B). *Study spectral de-mixing; within classes at the (sub-)pixel or level.*

In conventional classification methods, such as the ISODATA module in the ERDAS/IMAGINE system, pixels are allocated to a class just in terms of a particular class label. In our system, in addition to that, classes are characterized in terms of a univariate distribution along a linear segment, as determined by the first principal component of their singular value decomposition. Pixels can thus be represented as

particular distribution values within that class (the *blending* option). This makes it possible to attack mixed pixel blending as a mixture problem.

For instance, it was pointed out to us during the last meeting at CRREL RS/GISC that certain patches in the mountain area were labeled as belonging to the same class as water in the Painted Rock reservoir. Obviously, in actual applications one usually could seek to separate these classes by choosing a higher, more discriminating density value for class merging. This, however, would change the whole classification pattern and structure across the full image. Instead of that, in our case one could restrict oneself just to the investigation of the distribution within that class looking for multimodality or other mixing components. Using statistical demixing techniques one could thus decompose ('de-mix') that single class into sub-classes corresponding to 'shadow' and regular water. This approach might also be feasible for the analysis of snow cover.

Anticipated further work in this field is the development of non-parametric models more general then the linear singular value decomposition within classes. We will investigate whether recent neural network theory based on radial basis functions (RBFs), and the use of spiking neurons can show the same promises here as were propagated elsewhere. Together with the use of evolutionary computation methods to search for models for demixing of clusters consisting of multiple classes, and the usage of Bayesian methods to exploit the spatial the spatial structure during pixel classification. Spatial structure is exploited by computing prior probabilities over a spatial neighborhood, and use these to compute posterior pixel classification probabilities.

For all these studies we need images with varied reliable designated 'true' known ground knowledge patches. During our 5-7 October meeting at CRREL RS/GISC it was agreed with dr. LaPotin that we shall obtain at least three images to serve that purpose (oil spill, urban/rural, coastline areas, snow cover?).

C). Unsupervised change detection

In later stages of this project, assuming sufficiently confidence inspiring results from this research, we can try to make a start with the application of these methods and techniques of unsupervised classification to the corresponding multi-image problem of detecting change areas comparing two or more similar co-ordinated and registered images, such as, for instance, provided by time-sequential overpasses by LANDSAT TM RS imagery. Results in this respect might assist GIS-users in the area of emergency management.

(3) Significant administrative actions during the report period

During the reported period there has been no change in personnel involved in the project.

(4) Other important information

None

(5) Statement showing the amount of unused funds

See attachment.

Annex to

Fourth Interim Report Februari till April 1999
Unsupervised Spatial Feature and Change Detection in RS and Imaging

contract no. N 68171 98 C 9012
contractor Prof.dr R.J. Mokken
ALL/CCSOM, PSCW, University of Amsterdam

1. Statement showing amount of unused funds at the end of the covered period

2nd Incrementally Funded Period April 99 - March 00	total	$ 43,898
3rd Incrementally Funded Period April 00 - March 01	total	$ 48,867
total unused funds at end of covered period		**$ 92,765**

2. List of important property acquired with contract funds during this period